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Testing Methods for Gas Sensor Based Fire Detectors

VdS Testing Methods - Advantages and Disadvantages -
Suggestions for Improvement

Abstract

Within the past years fire detection technology has developed at a high speed of innovation. Computerization and the use of sophisticated fire detection algorithms gained more and more importance at taking advantage of the wide range of opportunities multisensor detectors show. Despite this development testing methods still remain to be the same. European testing standards and testing equipment that have been created for fire detectors decades ago are undergoing adoption to state of the art of fire detection technology step by step. Against this background the new VdS testing methods for gas sensor based fire detectors have been created basing on the European standard EN 54.

1 Introduction

Nowadays, fire detection technology is characterized by an increasing use of multisensor-detectors. In particular optical smoke sensors, ionization chambers and heat sensors are combined. By the continuous development of gas sensors, which are based on different physical and chemical principles, there is - in the meantime - the possibility to further improve multisensor-detectors by the additional use of gaseous fire criteria. Using suitable detection algorithms gas sensors can contribute to reduce the rate of deceptive alarms.

Furthermore, gas sensors seem to be suitable for the use in some special applications, in which conventional fire detectors are - due to the predominant environmental factors - not to be used or in which they cannot react sufficiently fast.

Gas sensor based fire detectors as well as conventional smoke- and heat detectors have to be subjected to a testing procedure in accordance with EN 54 to receive VdS approval. In this context, the University of Wuppertal, section fire and explosion protection, supports VdS Schadenverhütung at the development of a new testing procedure in design, realization, and testing out.

This paper gives an outline of VdS testing methods [1] for gas sensor based fire detectors. The advantages and disadvantages of the testing procedure will be illustrated and possible future solutions will be derived.

2 VdS Testing Methods for Gas Sensor Based Fire Detectors

In co-operation with industry and the University of Wuppertal and supported by the Institute of Applied Physics in Giessen, VdS Schadenverhütung has developed test guidelines for the testing of gas sensor based fire detectors.

As presented below the VdS-test procedure can be broken down into various modules:

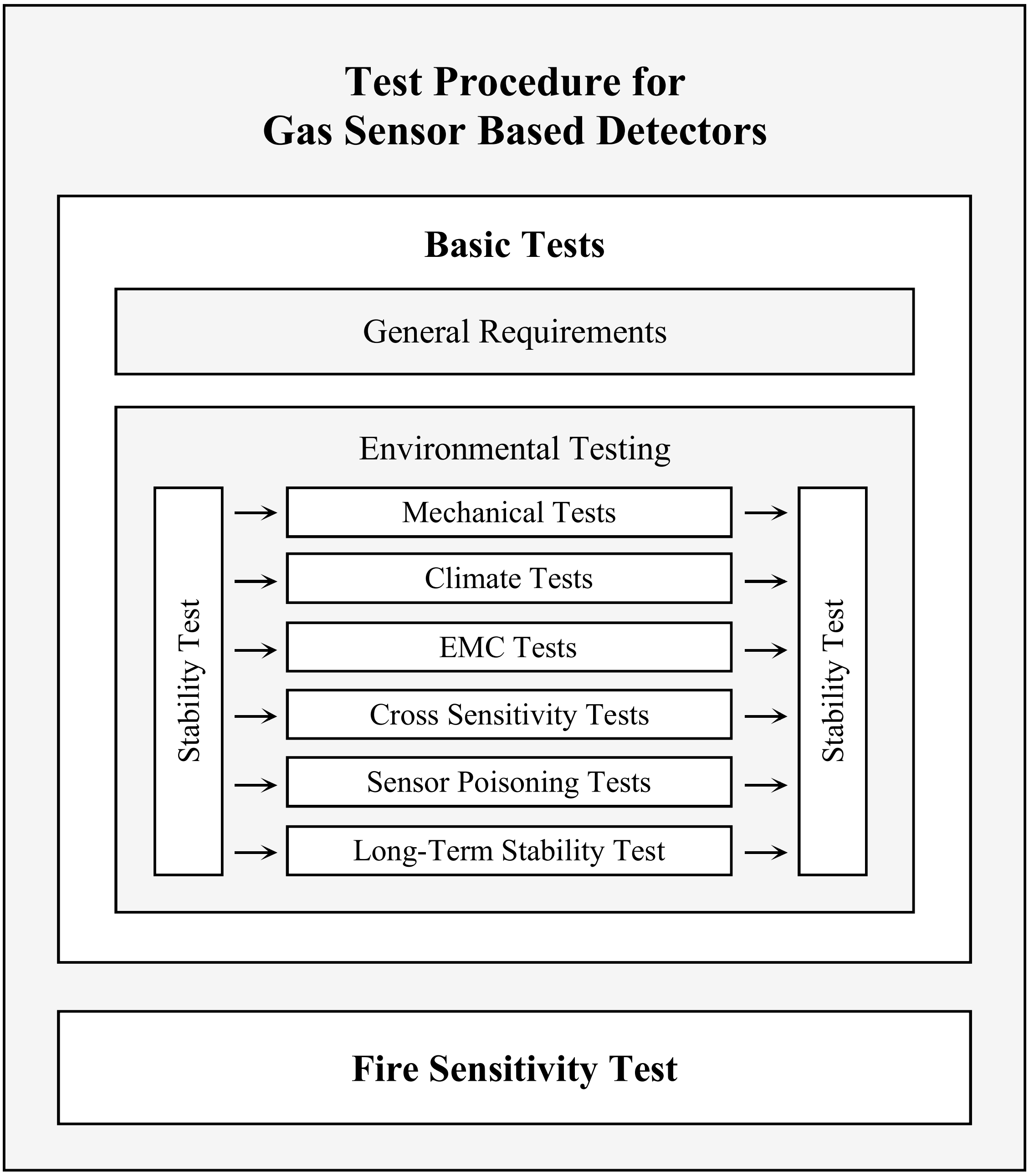

Figure 1: VdS test procedure for gas sensor based fire detectors

2.1 Environmental Testing

The requirements of the test methods, which is to assure the efficiency and the reliability of the individual components of fire detection systems, are described in the DIN EN 54 series of standards [3]. This series of standards also includes the functional testing of fire detectors with gas sensors (gas sensor based fire detectors). Section 1.3 of DIN EN 54, Part 1 stipulates:

> *"The fire detection system must not only work satisfactorily under the conditions of the fire event but also under environmental conditions which will normally occur in practice. The stipulated tests have the purpose to provide evidence for the performance of the system and its components under such conditions."*

The definition of this objective allows us to conclude that it is not necessarily sufficient to test fire detectors based on a new technology using a selection of existing tests in accordance with EN 54. Rather, it may be considered as an appeal to find out whether - and if so, which - additional tests may be necessary for the application of new technologies in fire detection in order to make sure that a detector will operate satisfactorily "also under environmental conditions, which will normally occur in practice". Against this background, new tests have been included in the test schedule for gas sensor based fire detectors and these have been chosen with respect to the well-known problems of *sensor poisoning* and *cross-sensitivities* found in many gas sensors.

Cross Sensitivity Tests

The occasionally insufficient selectivity of gas sensors includes the risk that gas sensor based fire detectors might be put in the alarm status by a large number of non-fire specific parameters [2]. For this reason, two deceptive alarm tests have so far been defined, where the detector must not emit an alarm signal. For the time being, the following parameters apply to the existing tests:

Deceptive parameter	Concentration	Test period
Ethanol (similar to [4])	500 ppm	1 h
Ammonia (similar to [5])	50 ppm	1 h

Sensor Poisoning Tests

In order to largely exclude “poisoning phenomena” of gas sensors in practical use, additional tests are carried out to determine the effect of sensor poisons. It should thus be determined, whether certain substances will irreversibly damage the sensors or negatively impact on the function of the test specimen or even prevent the detector’s use altogether. For the time being, two potential sensor poisons have been chosen:

Sensor poisons	Concentration	Test period
Ozone	500 ppb	1 h
Hexamethyldisiloxane (HMDS) (similar to [4])	10 ppm	1 h

In future it will probably be necessary to subject gas sensor based fire detectors to further tests for deceptive alarms and poisoning - depending on the sensors' principle. The ozone test concentration determined so far corresponds approximately to the maximum value which can be measured in the ambient air in summer. There are considerations to increase the requirements for this test.

2.2 Stability Test

According to the VdS testing methods and similar to the smoke (heat) channel for testing smoke (heat) detectors, a gas mixing apparatus is used for testing the signal reproducibility. This way of performing the stability test is - nowadays - the only one and logical means to establish defined testing methods for gas sensor based fire detectors within a short period of time.

The stability test is of crucial importance for the test methods for gas sensor based fire detectors. It is assessed by this test whether environmental impacts would have an inadmissible influence on the response behaviour of the sensor. For this purpose, the sensor to be tested will be defined before and after an environmental test and triggered in a reproducible fashion. The sensor signals triggered in this test will be compared to each other; the deviation of the signalling behaviour induced by the influence of the environmental test must not exceed a predetermined level.

Testing Procedure

The defined triggering of sensors takes place by exposing the entire detector to a test gas mixture of CO_2, CO, H_2 and NO_2 at defined temperature and humidity. The components of this gas mixture are gases, which are generally considered as the predominant gases emitted by burning processes; the relation of the individual concentrations corresponds to that of a mixed fire (smouldering/glowing fire plus open fire). If a gas sensor responds to different target gases/steams it may be necessary to add these substances to the test gas mixture or to impact the sensor with these substances separately.

For this test, VdS purchased a gas mixing apparatus, which - after a short lead time of a few minutes - is able to generate the gas concentrations stipulated in the test methods for the entire range of defined parameters:

- Gas ratios: 2000 parts CO_2, 100 parts CO, 20 parts H_2, 1 part NO_2
- Total gas flow: (0.2 … 1) l_n/min
- Temperature: up to 40 °C (standard: 25°C)
- Relative humidity: up to 50% at 40°C (standard: 50% r.h. at 25°C)

In order to achieve defined test conditions, the test specimens are exposed to the test gas mixture after setting the gas concentrations and humidity and temperature to a steady state. Prior to this exposure, each test specimen is exposed to air-conditioned synthetic air in line with the respective test conditions in order to avoid a sensor reaction triggered by climatic change.

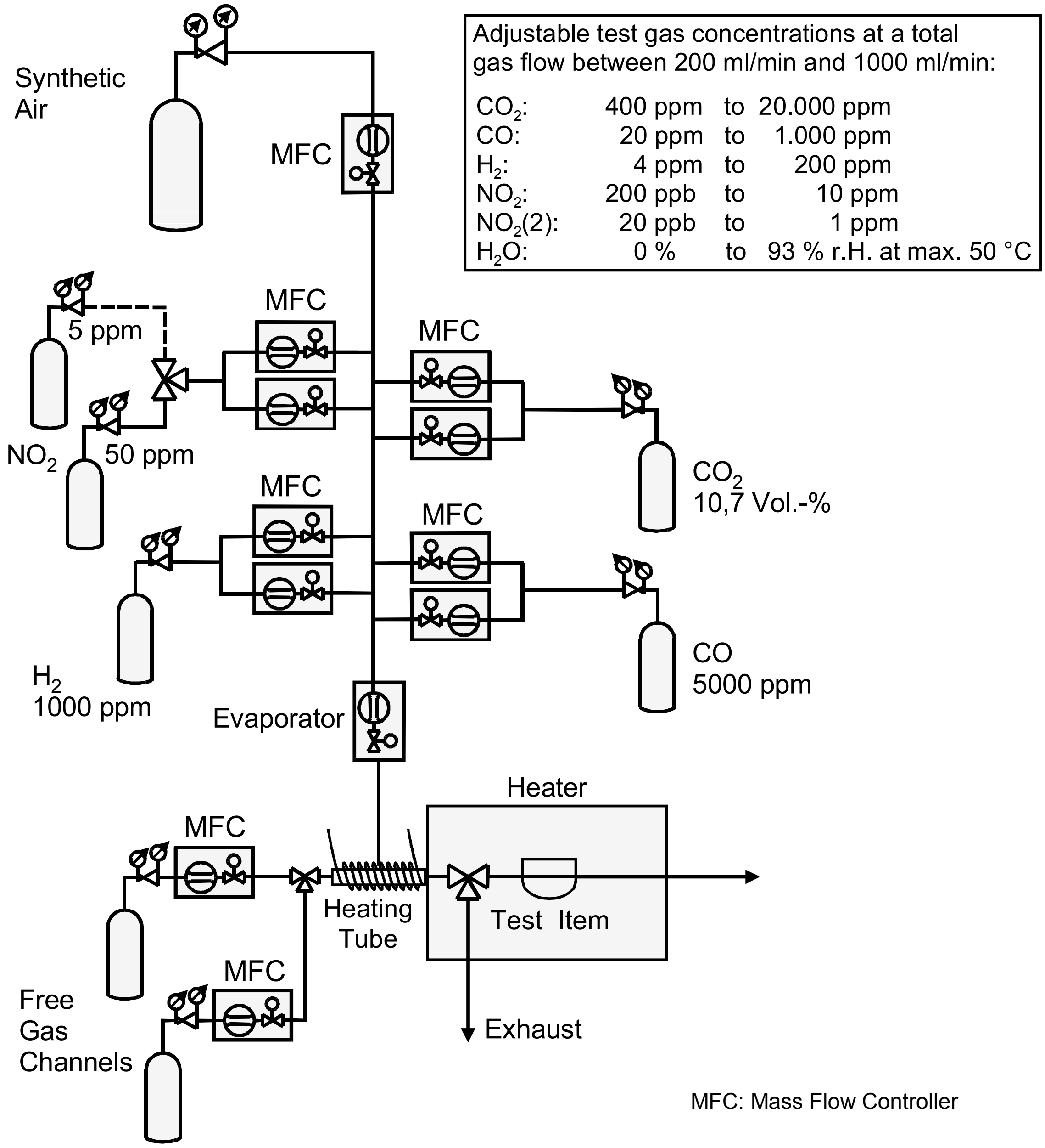

Figure 2: Gas mixing apparatus for testing gas sensor based fire detectors

Problems

For the reason that gas sensors can be expected mainly to be implemented in multisensor-detectors, it usually will not be possible to force an alarm by the use of a *gas* mixture alone. All sensor signals must therefore be measured out individually and be evaluated. So the following problems can be derived:

- Measuring out and *evaluating each single sensor* signal requires high testing costs.
- The *measuring range* of a gas sensor which actually is evaluated cannot be defined by objective criteria. Practical criteria must be used for an „artificial specification“ of the range.
- Often several gas sensors build up a "*Sensor Array*". The testing of every single sensor within a larger array would mean unacceptable high testing costs. Therefore sensor arrays shall be tested as one unit. But in practice it is not possible to generalize criteria for the decision whether one detector possesses X single gas sensors or if it has just one Array from X sensor elements.
- The algorithm determines the *weight of the influence of a single sensor signal* on the evaluation of the detector. For instance rather unstable sensors can produce additional fire criteria by providing a trend evaluation without impairing the stability of the detector. For this reason the stability demands on a sensor should theoretically take into consideration its influence on raising the alarm; however, this is not possible to be put into action.
- The reproducibility of a detector’s response behaviour does not necessarily correspond with the reproducibility of its single sensor signals. A stability test which is based on the measuring out and evaluating of the single sensor signals does not take into account the *influence of the software* on the detector’s response behaviour at all.
- An *interface* must be defined for measuring out the single sensor signals. Already existing detectors which do not fulfil the corresponding demands may not be testable.
- Some gases and steams *can not be mixed* with the standardized gas mixture and have to be given to the detector separately. This would mean additional testing efforts and increasing testing costs.

All of the above mentioned problems can directly be derived from the state of the art of testing methods. Against the background of increasing importance of data processing during the past years it is not acceptable to further neglect this factor for future testing.

Especially the value of additional gas sensors within multisensor/multicriteria fire detectors absolutely depends on the use of sophisticated algorithms. A test procedure for those detectors should therefore evaluate the detector as a whole. This can only be done by evaluating the alarm signal.

For triggering an alarm signal multicriteria detectors have to be exposed to a fire-like mixture of particles, heat and gases. At the National Institute of Standards and Technology (NIST) a testing apparatus [6] has been built, which - for instance - could be used for this kind of testing.

Black-Box-Testing

Being able to provoke an alarm signal at multisensor/multicriteria detectors the question has to be answered, how the stability of a detector's response should be evaluated. Theoretically the detector could be tested as a black box - no matter how it functions and which are the sensing principles it is based on. But the information that can be extracted by "black-box-testing" is not sufficient for evaluating a detector's response stability for two reasons:

- By using this testing method alone it may be impossible to make out a severe damage of a single sensor. This means a loss of a sensor may be without consequences for the detector's behaviour under the testing conditions.

- Actually it is rather common to design special environment tests for individual sensor techniques. Characteristics which could potentially turn out as problematic on site have to be checked up on within the scope of functional testing. If it is not obvious on which sensing principle(s) a fire detector is based on, it has to be supposed that it shows the whole range of problematic characteristics for all kinds of principles. This way testing efforts would have to be risen dramatically to achieve the same degree of functional safety as it can be achieved with state of the art testing.

Solution

For these reasons both has to be done, primarily the reproducibility of raising the alarm should be used as test criterium, furthermore the individual sensor signals should be evaluated (in a moderate way) to be able to recognize severe sensor damages and to be able to test a detector not more intensively (and costly) as necessary. This way the positive aspects of "black-box-testing" can be combined with the advantages of today's testing methods excluding all of the disadvantages of state-of-the-art testing mentioned above.

But a testing procedure considering the importance of the software has to take into account, that a fire detector may use two or more different algorithms for detecting open fires and for detecting glowing/smouldering fires. In case of multisensor detectors these algorithms can be supposed to be based on different sensor signals. Whereas a glowing fire optimized algorithm might evaluate the signals of both a CO-sensor and a smoke sensor, an open fire optimized algorithm might evaluate smoke density and temperature. So, a fire detector has usually to be seen as a combination of independent parts, which have to be tested separately with open fire emissions and with emissions of a smouldering fire.

2.3 Fire Sensitivity Test

The fire sensitivity test for gas sensor based fire detectors - as for smoke detectors - is to be carried out initially with the test fires TF 2 to TF 5 stipulated in DIN EN 54 Part 9 [7]. These fires include smouldering and glowing fires as well as open fires. They have been developed to create a wide range of smoke particles and heat radiation intensities in a reproducible fashion.

Gas sensor based fire detectors very often contain CO- and H_2-sensors. Therefore, they potentially have special advantages in the detection of fires with a long smouldering phase; so in principle they are suitable for very early fire detection. Nonetheless, gas sensor based detectors quite often show problems (due to their temperature cycles and measuring cycles) in detecting test fires according to DIN EN 54 within the stipulated time limit. The reason is that the test fires described are open fires and artificially accelerated smouldering or glowing fires. These fires are not suitable to bring out the time advantage of a fire detector which really shows a special suitability for very early fire detection.

In practice, most fires have more or less extensive fire development phases (cf. figure 5); exceptions are liquid fires and fires of melting plastics. Only a test fire showing a longer fire development phase (which provides a sufficiently long time for the detector to make a safe alarm decision based on characteristic parameters of the "genuine” development of a fire) is suitable for the assessment of the detection delay in gas sensor based fire detectors. For the testing these detectors it therefore seems to be necessary to develop test fires, which reproduce the smouldering and glowing phases of fires in line with practical conditions.

There can be no doubt that also conventional fire detectors should have the possibility to pass such kind of test. As a result an optional test should be offered - with no regard to the sensing principles - to evaluate the ability of detecting fires during the very early phase.

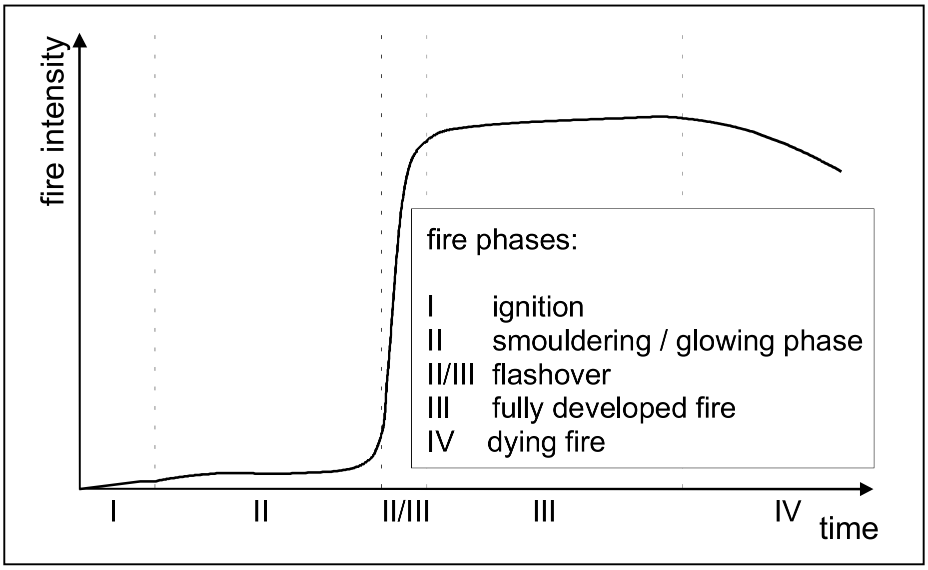

Figure 3: Fire phases, modified according to [8]

3 Discussion

So far, the VdS test methods for gas sensor based fire detectors consider semiconductor sensors, electrochemical cells, optical gas sensors and opto-electrodes as sensing principles. It can safely be assumed that in the future further gas detection principles will be suitable for fire detection. It has also to be expected that new variations of well-known technologies will be used, which require several modifications of the existing test methods. Against this background, it seems - by now - to be necessary to orientate the requirements of test methods not only to existing technologies and thus not to develop unnecessary barriers for future developments.

As important as it was to conceive test methods for gas sensor based fire detectors as fast as possible, it is equally important now to make these methods adjustable to new developments. In this context, framework specifications might be useful, which define the basic requirements for gas sensor based fire detectors (“performance standard” versus “design standard”). The associated requirements and test methods might then be determined for the individual sensor principle in the corresponding “implementation” guideline. Thus it might be possible to prevent that a test will gradually become more important than the purpose, for which it was originally developed.

4 Literature

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